Symons's Meteorological Magazine. London. Vol. 37.
—— The Sun Pillar of March 6. Pp. 33–34.
Johnson, S. J. Conspicuous Sun Pillar. P. 34.
—— The Rainfall of Madeira. Pp. 37–38.
—— On the use of our Rainfall Tables. Pp. 49–50.
Dines, W. H. A new Kite for Meteorological purposes. Pp. 51–53.
Nature. London. Vol. 65.
Cornish, Vaughan. Sun Pillars. P. 560.
Hunt, A. R. Municipal Meteorology, P. 561.
Foster, M. The Regina Margherita Observatory. Pp. 568–569.
—— The Photography of Disturbances of Air. Pp. 575–576.
Nature. London. Vol. 66.
Cox, John. On Professor Arrhenius' Theory of Cometary Tails and Auroræ. P. 54.
Halm, J. On Professor Arrhenius' Theory of Cometary Tails and Auroræ. Pp. 55–56.
Comptes Rendus de l'Académie des Sciences. Paris. Tome 134.
Guillaume, J. Observations du soleil, faites à l'Observatoire de Lyon (équatorial Brünner de 0.16 mètre), pendant le quatrième trimestre de 1901. Pp. 892–894.
Teisserenc de Bort, L. Variations de la température de l'air libre dans la zone comprise entre 8 kilomètres et 13 kilomètres d'altitude. Pp. 987–989.
Moureaux, Th. Sur la pluie d'encre du 7 mai 1902. Pp. 1107–1108.
Annuaire de la Société Météorologique de France. Paris. 50me Année.
Teisserenc de Bort, L. Note sur quelques résultats des ascensions de ballons-sondes à Trappes. Pp. 49–52.
Goutereau, Ch. Sur les résultats du tir au canon contre la grêle. Pp. 52–59.
Bruel, G. Note sur la météorologie du Haut-Chari. Pp. 69–77.
Rotch, Lawrence. Sondages atmosphériques exécutés l'aide de cerfs-volants à Blue Hill. Pp. 78–80.
Journal de Physique. Paris. 4me Série. Tome 1.
Baillaud, Jules. Sur la variation de la réfraction atmosphérique. [Note on article by G. Saija.] P. 319.
Baillaud, Jules. Sur les variations diurnes de la réfraction atmosphérique. [Note on article by Vittorio C. Boccara.] Pp. 319–320.
La Nature. Paris. 30me Année.
Rabot, Charles. Les variations dans les précipitations atmosphériques. Pp. 370–371.
Annales de Géographie. Paris. 11me Année.
Blanchard, Raoul. La pluviosité de la plaine du nord de la France. Pp. 203–220.
Ciel et Terre. Bruxelles. 22me Année.
Lancaster, A. Les précipitations météorologiques sur les pentes des montagnes. [Review of article by E. Pockels.] Pp. 93–97.
Lancaster, A. Les refroidissements périodiques de mai. Pp. 111–119.
Very, F. W. Un cycle cosmique. Pp. 120–127.
—— La variation séculaire de la pluie. P. 133.
Annalen der Hydrographie und Maritimen Meteorologie. Hamburg. 13 Jahrgang.
Dinklage, L. E. Resultate meteorologischer Beobachtungen der Höhenstation Monte Café auf der Insel San Thomé, Westafrika. Pp. 202–215; 239–249.
Schott, Gerhard. Die Wärmevertheilung in dem Wasser der südpolaren Meere. Pp. 215–224.
—— Die Witterung zu Tsingtau im Dezember 1901, Januar und Februar 1902 nebst einer Zusammenstellung für den Winter 1901–1902, Pp. 235–238.
Dinklage, L. E. Der Südwestmonsun im Nordatlantischen Ozean. Pp. 255–257.
Gaea. Leipzig. 38 Jahrgang.
Klein, H. J. Lowells neue Untersuchungen über die klimatischen Verhältnisse auf dem Planeten Mars. Pp. 326–330.
—— Der grosse Staubfall vom 9 bis 12 März 1901 in Nordafrika, Süd- und Mittel-Europa. Pp. 330–336.
—— Der Hauptergebnisse der gleichzeitigen Ballonfahrten am 8 November 1900. Pp. 336–340.
—— Der Einfluss des Windes auf die Vegetation der ostfriesischen Inseln. Pp. 377–378.
Das Wetter. Berlin. 9 Jahrgang.
Sieberg, A. Das Photographiren von Halos. Pp. 81–84.
Grohmann, —. Die klimatischen Verhältnisse des Königreiches Sachsen in ihrer Abhängigkeit von Luftdruck und Windursprung. Pp. 84–89.
Treitschke, Friedrich. Eine ungewöhnliche Depression der Hygrographenkurve in Erfurt. Pp. 91–92.
Kassner, C. Schöne Haloerscheinung in Berlin. Pp. 92–93.
Physikalische Zeitschrift. Leipzig. 3 Jahrgang.
Elster, J. und Geitel, H. Beschreibung des Verfahrens zur Gewinnung vorübergehend radioaktiver Stoffe aus der atmosphärischen Luft. Pp. 305–310.
Wiechert, E. Polarlichtbeobachtungen in Göttingen. Pp. 365–366.
Annalen der Physik. Leipzig. Vierte Folge. Band 7.
Quincke, G. Ueber unsichtbare Flüssigkeitsschichten und die Oberflächenspannung flüssiger Niederschläge bei Niederschlagmembranen, Zellen, Colloiden, und Gallerten. P. 701–745.
Olszewski, K. Bestimmung der Inversionstemperatur der Kelvin'schen Erscheinung für Wasserstoff. Pp. 818–824.
Zeitschrift für Gewasserkunde. Leipzig. 4 Band.
Gravelius, H. Einrichtung des Hochwassernachrichtendienstes im bayerischen Donaugebiet. Pp. 257–268.
Crugnola, Gaetano. Zur Dynamik des Flussbetts. Pp. 268–304.
Zeitschrift der Gesellschaft für Erdkunde zu Berlin. Berlin. No. 3. 1902.
Ramann, E. Das Vorkommen klimatischer Bodenzonen in Spanien. Pp. 165–169.
Illustrirte Aeronautische Mittheilungen. Strassburg. Nr. 2. 1902.
Trabert, Wilh. Bildung und Konstitution der Wolken. Pp. 70–72.
Ritter, Friedrich. Hervorragungen und Winddruck. Pp. 88–91.
Meteorologische Zeitschrift. Wien. Band 19.
Polis, P. Zur täglichen Periode des Niederschlages. Pp. 145–161.
Sandström, J. W. Ueber die Beziehung zwischen Temperatur und Luftbewegung in der Atmosphäre unter stationären verhältnissen. Pp. 161–172.
Woeikof, A. Klima der Stadt und Forstei Uralsk. Pp. 172–175.
Hergesell, H. Vorläufiger Bericht über die internationale Ballonfahrt am 9 Januar 1902 (und Nachtrag vom 5 December 1901). Pp. 175–176.
Sapper, K. Meteorologische Beobachtungen in der Republik Guatemala im Jahre 1900. Pp. 176–180.
Hellmann, G. and Meinardus, W. Hauptergebnisse einer Untersuchung über den grossen Staubfall vom 9–12 März 1901 in Nordafrika, Süd-und Mitteleuropa. Pp. 180–184.
Duffeck, J. Ueber das Wesen der Gewitter und Andeutungen über das Entstehen der Polarlichter. Pp. 184–185.
Prohaska, K. Gewitter am 17 und 18 December 1901. Pp. 185–186.
Hann, J. Klimatabelle für den Mont Ventoux. Pp. 186–188.
—— Resultate der meteorologischen Beobachtungen zu Lausanne. P. 188.
—— Der tägliche Gang des Luftdruckes und der Temperatur auf dem Ben Nevis und an dessen Fuss zu Fort William an der Küste. Pp. 188–189.
—— Mondphasen und Gewitterfrequenz. P. 189.
Wolfer, A. Provisorische Sonnenflecken-Relativzahlen für das I Quartal 1902. P. 189.
Bollettino Mensuale, Società Meteorologica Italiana. Torino. Serie 2. Vol. 21.
Cittadella, A. Ancora sulla pioggia detta (pioggia di sangue), del 10 marzo 1901. Pp. 53–55.

THE RELATION OF THE SUN-SPOT CYCLE TO METEOROLOGY.[1]

By C. G. ABBOT, dated April 10, 1902.

Since the discovery of the periodicity of sun spots, a large place in scientific literature has been occupied by articles tending to establish some connection between this and variable terrestrial phenomena. It is natural that it should be inferred that any considerable change in the sun must bring about numerous direct or indirect consequences upon the earth, but one who has given the subject no attention will be startled to find that the following list contains but a portion of the terrestrial phenomena asserted, on more or less authority, to be influenced by the sun-spot cycle: Magnetic and electrical conditions, including the aurora borealis; air temperature; barometric pressure; humidity; the winds; cloudiness; rainfall; depth and quantity of discharge of rivers; retreat and advance of glaciers; number of shipwrecks; bank failures and commercial crises; the crops; prices of grain; famines; wars, and even flights of butterflies.

It would probably be easier to show that the number of articles concerning sun spots in scientific periodicals has an 11-year period than to prove all the above-mentioned relations to the general satisfaction. For the purposes of this paper it will be sufficient to assume as proven that terrestrial magnetism and the aurora borealis are affected when spots appear upon the sun; and that while the evidence is less simple in regard to the meteorological elements, temperature, barometric pressure, humidity, cloudiness, and rainfall, yet there is good reason to think that these, too, are somewhat connected with the sun-spot cycle.

[1] Published by permission of the Secretary of the Smithsonian Institution.

FIG. 1.—Montpellier observations with Crova self-registering actinometer. Mean of noon, by years, 1883–1900.

HOW SUN SPOTS MAY BE ASSOCIATED WITH TERRESTRIAL PHENOMENA.

The question before us is this: Through what physical connection is the presence of sun spots associated with variations in terrestrial magnetism and with meteorology? The question suggests the possibility either of a single or a dual link between the solar and the terrestrial occurrences. It is conceivable, for instance, that the sun spots are associated with great electro-magnetic disturbances upon the sun which are propagated to the earth and directly disturb terrestrial electricity and magnetism, and that such a disturbance of atmospheric electricity as thus occurs may indirectly induce or prevent the accumulation of clouds, which in turn may bring on differences in temperature, barometric pressure, and rainfall. Again, it is conceivable that sun spots are associated with an increase or a diminution of the sun's radiation, which obviously would directly affect meteorology, and indirectly might affect terrestrial magnetism and electricity. Still again it might be that the sun spots are associated both with great electro-magnetic disturbances in the sun and with an increase or diminution of solar radiation, and that in this dual way the terrestrial changes are directly brought about.

The second of these hypotheses is, I think, untenable, as an explanation of the magnetic effects. These are too quick and pronounced to allow us to suppose for a moment that they are the indirect results of increased or decreased solar radiation. We may then admit that electro-magnetic disturbances are propagated from the sun at the time of sun spots. It would be difficult, however, to prove or disprove that these are competent to indirectly produce the observed fluctuations of temperature, pressure, and humidity which have been connected with the sun-spot cycle. Almost without exception, writers on this subject who have ventured an opinion have attributed these meteorological changes to alterations in the amount of the solar radiation. There seems to be a preponderance of suggestion that the sun radiates more at sun-spot maximum, although there are not wanting many who hold precisely the contrary opinion.

METHODS OF DETERMINING THE SUPPOSED VARIABILITY OF SOLAR RADIATION—SOLAR ACTINOMETRY.

It would seem at first sight a simple thing to show whether the sun radiates more at one time than at another by a direct exposure of a suitable actinometer during a term of years. This has been done in several instances, but so far as I know with a wholly unconvincing result. About twenty years ago, for instance, two able gentlemen reduced, independently, such a series of observations extending over a sun-spot cycle and deduced, the one that the sun's rays were appreciably more intense at sun-spot maximum, the other the exact opposite. Nor are later results with the most perfect apparatus more convincing. The illustration (fig. 1) is plotted from observations extending back to the year 1883, taken at Montpellier with the Crova self-recording actinometer, an instrument of highly approved construction and most ably and honestly used. The ordinates represent yearly means of all noon observations taken on clear days. While large fluctuations in the curve are evident, any connection between them and the 11-year sun-spot period, whose maxima occurred in 1883 and 1894, is hard to recognize.

EFFECTS OF ATMOSPHERIC ABSORPTION.

Shall we then conclude that the negative of the question is proved, and that the solar radiation does not vary to any considerable extent periodically along with the presence of spots upon the surface of the sun? This conclusion would be premature. The observer at the earth's surface sees the sun much as a fish at the bottom of the lake sees the clouds. More than one-half of the sun's radiation which reaches the outer layers of the earth's atmosphere is reflected or reradiated away or is absorbed within the atmosphere, and fails wholly to reach the earth's surface, except as heat produced by absorption, and communicated chiefly by convection and precipitation. The atmosphere is constantly varying in its transparency. These changes are chiefly caused by water vapor, water globules, and dust becoming more or less abundant, and are so great that even the largest depressions in the curve of actinometer results, just given, might easily be thus caused. Indeed, it occurs to me, and may very likely have occurred to others, that the great depression in the curve for the years 1884, 1885, and 1886 was caused by the presence in the air of dust from the remarkable eruption of the volcano of Krakatoa in the summer of 1883.

To emphasize the importance of the influence of water vapor on actinometric observations, attention is called to a second curve (fig. 2) plotted from the Montpellier observations, showing the average yearly fluctuation of solar radiation observed. The ordinates represent the monthly means of the noon observations from 1883 to 1900. It will immediately occur to the reader that these observations are not taken at a constant altitude of the sun, so that the effects of different thicknesses of the air column must influence the curve as well as those of different humidity and the like. But a little further reflection will show that two months at equal intervals before and after the solstices are comparable so far as the altitude of the sun is concerned. Thus, for example, July and May, August and April can be compared on an equal basis. Such a comparison brings out very clearly the great difference in transparency of the air between the spring and summer months, a difference which, as was pointed out in Volume I of the Annals of the Smithsonian Astrophysical Observatory, is chiefly caused by the comparative absence of water vapor in the air during the spring months. Recent unpublished spectrobolometric studies at the Astrophysical Observatory show that on two apparently equally clear days, near the middle of March, 1902, with equal altitudes of the sun, the difference in the absorption in the well-known visible and infra-red water-vapor bands alone was such as to cause a difference in the solar radiation at the earth's surface of 7 per cent. Changes far in excess of this occur from the same cause between spring and summer.

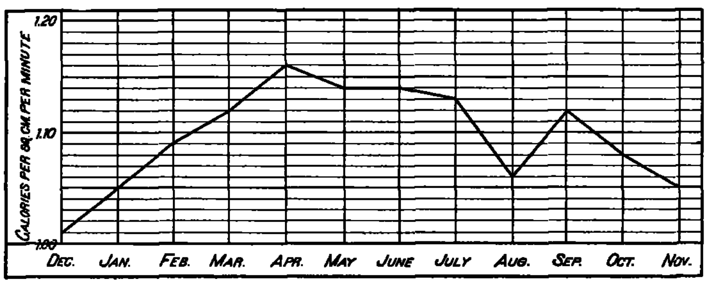

FIG. 2.—Montpellier observations with Crova self-registering actinometer. Mean of noon values by months for years 1883-1900.

In view of these facts, it is not going too far, I think, to say that no amount of actinometric observations of the *total solar radiation* can ever furnish a proof of the sun's variability, so long as the earth's atmosphere intervenes. Such observations, to have weight to decide this question, must be conducted as high above the earth's surface as is possible.

SPECTRAL ACTINOMETRY.

There remains, however, another method of attack less indecisive. Imagine for a moment that there may be a certain wave length for which the earth's atmosphere is perfectly transparent, so that changes in water-vapor content and the like are unable to alter the quantity of rays of this wave length which reach the earth's surface. If such a region in the solar spectrum exists and if the actinometric observations be confined to it, there would be the possibility of determining any variability of the sun's radiation for this particular wave length. Still, of course, there would remain the chance that the amount of emission in other regions of the spectrum might vary and become stronger or weaker without affecting this one. Let us, however, still further assume that other regions of the spectrum exist where the atmospheric absorption, though not negligible, is of a kind directly calculable with certainty, knowing the air mass traversed by the rays, by the aid of a suitable formula. Here, again, there would remain the possibility of determining the sun's variability from actinometric observations confined to these regions of the spectrum. If a sufficient portion of the spectrum satisfying these requirements exists, the possibility, just alluded to, of failure to discover the range of wave lengths where the solar emission is variable, would be avoided to a great degree. To restate the advantages of spectral actinometry over actinometry of the complete solar radiation, the former allows the observer to avoid altogether the errors introduced by the presence of water vapor and other bands of variable atmospheric absorption, and to confine his measures to wave lengths whose transmissibility by the atmosphere is less fluctuating and more certainly determinable.

Without speaking too confidently in a matter of such difficulty, I am inclined to think that regions of the solar spectrum exist whose transmissibility in the atmosphere may be closely determined and in which spectral actinometry may be carried on, even at the earth's surface, in such a way as will determine satisfactorily whether the emission of the sun has an 11-year period or not. It may be of interest to add that spectrobolometric observations of this kind are now in progress at the Smithsonian Astrophysical Observatory. It can not be denied, however, that still greater certainty and value would be added to this work if it were conducted high above the lower strata of the earth's atmosphere.

DIRECT OBSERVATIONS OF THE SUN.

The direct examination of the sun's surface by suitable optical methods has yielded interesting facts connected with the sun-spot cycle and the question of a possible variability of the solar radiation. Thus, continuous records are being kept at several observatories of the spotted area of the sun and of the appearance of faculæ and prominences, notably in Italy. At every total solar eclipse numerous photographs of the corona and of the spectra of the various solar appendages continue the incomplete records of these phenomena. Furthermore, the Solar Physics Observatory at South Kensington, under the efficient direction of Sir Norman Lockyer, has for many years collected photographic spectra of the sun spots for comparison with the spectra of the surrounding photosphere.

Broadly speaking, the results of routine solar study indicate that there is associated with the maximum of sun spots a maximum period of activity in solar phenomena of other kinds. This includes an enlarged extent of surface covered by facula and eruptive prominences and increased brightness of the corona. It is a natural, though not a necessary, inference that along with this increase of visible disturbance there will go an increase of radiation emitted, just as when we stir a fire and bring fresh coals to the top, it sends out the more radiation.

Sir Norman Lockyer goes further than this in discussing the differences between the spectra of spots and the spectra of the photosphere, and seems to affirm very distinctly, as proved beyond reasonable doubt, that the sun is actually hotter at sun-spot maximum. It is observed at South Kensington that some of the spectral lines within the spots are broadened as compared with the same lines in the spectrum of the photosphere. The lines most broadened at sun-spot minimum are those which appear as emission lines in the spectra of known terrestrial substances, as such spectra are produced by introducing metals in the electric arc, or, in similar fashion, while the lines most broadened at sun-spot maximum do not correspond to the emission spectra of known terrestrial substances, but have their origins unknown. By a plausible inference in the nature of an extrapolation from known data, Lockyer thinks these unknown lines widened in the spots are due to simpler atomic (or lesser than atomic) combinations, made possible only by higher temperatures than those at our command in the laboratory. Hence, he concludes that the sun spots are hotter at sun-spot maximum than at sun-spot minimum, and that their increased temperature indicates a hotter sun and greater emission. This argument, if I rightly apprehend it, is not entirely conclusive, for even if we accept the first assumption in regard to the nature of the "unknown" lines and admit that the sun spots are hotter at sun-spot maximum, it still seems possible that the higher temperature of the spots may be otherwise caused than by a hotter sun, for we may see deeper down in the spots at maximum than at minimum, and view them at maximum at a depth where they are surrounded by the hotter interior of the sun. If, however, direct spectral actinometry, such as I have spoken of above, should be carried on for a term of years at some high altitude, and should conclusively determine the amount and kind of changes which may be taking place in the emission of the sun, then it might prove, not only that Lockyer's views are indeed the true ones, but that his method of observation, while not independently yielding a rigid proof of a variable solar emission, would still be the best suited to keep account of the fluctuating condition of the sun after such a variability has been thoroughly established.

THE INFLUENCE OF SOLAR ATMOSPHERIC ABSORPTION.

Some work has been done by heat methods and by photometry to compare the radiation of the spots with that of the photosphere, notably by Langley about 1875. This work shows that the spots radiate distinctly less than the photosphere surrounding them, though not so much less that the radiation received from a spot at the center of the sun's disc would fall below the amount received from an equal angular area of the sun's disc near the limb where it suffers great absorption in its long path through the solar atmosphere. Langley showed indeed that the direct influence of spots in diminishing the total radiation of the sun is not worth taking into account. At about the same time the investigations of the absorption of the sun's atmosphere by Langley, Vogel, and others showed how marked an iufluence this solar atmospheric absorption exerts on the amount of solar radiation received at the earth. It would probably be within bounds to say that a quarter of the radiations of that interior surface, which may roughly be spoken of as the radiating surface of the sun, are stopped by what may roughly be called the solar atmosphere.

Halm, in papers which appeared in recent numbers of the Astronomische Nachrichten and of Nature, uses this absorbing property of the solar atmosphere as the basis of a most ingenious theory to account for the periodicity of sun spots and the other associated periodic solar phenomena as well as of differences of emission which may exist. His discussion leads to the view that the solar radiation emitted is less as the sun-spot maximum period approaches, and that the spots, prominences, and faculæ are the volcanic evidences of a superheated condition within, which has resulted from a restriction of the freedom of radiation by the cooling and consequent increasing opaqueness of the outer layers of the absorbing atmosphere. The interior of the sun is heated by contraction, according to Halm, faster than its atmosphere allows the heat to be diminished by radiation, Thus a periodic restoration of the temperature equilibrium must take place. This is brought about by the increased circulation, reheating, and resulting greater transmissibility of the solar atmosphere. By this view the atmosphere, after such a gradual increase of transmissibillity, which reaches its maximum long after the maximum of sun spots, becomes more opaque again by gradual cooling of its outer layers during the succeeding relatively calm state. The truth of this could be determined by observations of the radiation from different parts of the sun's disc with the spectrobolometer of Langley, or with the spectral photometer of Vogel. Such an investigation to determine the transmissibility of the solar atmosphere by observations of the energy spectra at different parts of the sun's disc has been made within the past year at the Smithsonian Astrophysical Observatory. If continued for a period of eleven years this study ought to show any such variations of transmissibility as Halm's theory requires.

CONCLUSION.

These new views then, like all their predecessors, point to the complexity of the sun, and the uncertainty of deductions based on our present knowledge. At the same time the probability of a vital connection between the solar changes and matters of great interest upon the earth has been more and more confirmed within the last thirty years. It would seem that satisfactory progress in our understanding of these relations requires that observations of the energy of the solar spectrum be carried on at the highest practicable altitude in or near the Tropics, for a term of years that shall be not less, but preferably more, than a complete sun-spot period of eleven years. Such an investigation would determine, it may be hoped, whether or not the sun emits different quantities of radiation in different years; whether observations at lower altitudes may be relied upon to follow the sun's condition, and it might also throw light on the cause of solar periodicity.

THE CIRCULATION OF THE ATMOSPHERE IN THE TROPICAL AND EQUATORIAL REGIONS.

By A. LAWRENCE ROTCH, Director, Blue Hill Meteorological Observatory, dated May 6, 1902.

It is evident to students of meteorology and physical geography that our theories about the circulation of the atmosphere above the trade winds and doldrums are based on very scanty data and consequently that any method of increasing our knowledge of the subject should be welcomed. After I had demonstrated last summer that kites could be employed on a steamship to obtain meteorological observations in the upper air during both calm and windy weather, and in regions hitherto inaccessible (see MONTHLY WEATHER REVIEW, September, and December, 1901), it seemed that the most useful field for kites was the equatorial and tropical oceans. With a view of ascertaining the state of our knowledge on the subject, as well as when and where atmospheric soundings should be made, I consulted Prof. H. H. Hildebrandsson, of Upsala, Sweden, who, by reason of his discussion of the international cloud observations and measurements, and the attention he has given to the study of the circulation of the atmosphere, is one of the best authorities on the subject. With the consent of Professor Hildebrandsson, his answers to my inquries are here given almost verbatim.

THE UPPER ANTITRADE AND ITS INVESTIGATION.

Theories of atmospheric circulation.—It has been believed from the time of Halley, and more fully developed theories have been put forward by Dove, Maury, and Ferrel, that the ascending currents above the thermal equator proceed immediately as southwest and northwest antitrades over the northeast and southeast trade winds. A part of the antitrade, perhaps, sinks down over the high barometric pressures in the North and South Atlantic oceans and returns with the trade winds, but the greater part of the antitrade first descends to the surface of the ocean north and south of the trade winds and continues to the poles as the prevailing southwest or northwest winds of the north or south temperate zones. The facts upon which this theory is based are very meager. It is only on the Peak of Teneriffe (12,180 feet) that the antitrade can be observed the whole year. Its mean lower limit is at the height of 9,000 feet, and this height is greater in summer than in winter. In October it sinks to 6,000 feet. Leopold von Buch (as cited by Dove, Das Gesetz der Sturme, p. 27) wrote in 1825, as follows: "Should we not believe that the west wind sought for on the summer voyages from Teneriffe to England in the latitude of the Azores and ordinarily found there * * * is, as well as the west wind on the summit of the Peak, the upper equatorial current that has here come down to the level of the sea? It would then follow that the equatorial current of the upper regions, at least over the Atlantic Ocean, does not reach the pole."

So far as I know this is the only empirical fact upon which the theory is founded, but, on the other hand, it should be said that it is not proved that the surface wind at the Azores is the prolongation of the antitrade. When the center of the barometric maximum shifts to the south, the southwest wind also moves to lower latitudes, and as the antitrade sinks near the center at the same time, it probably must be at a lower level on the Peak when the center is approaching. But, as already stated, it is not certain that the antitrade reaches the surface of the ocean north of this center of high pressure.

Ascertained facts.—Our knowledge is very limited. We know that the antitrade exists over the trades, at least in the north Atlantic and at the Sandwich Islands, but no one has found this upper current in Central America or in Ecuador, while the smoke of the highest volcanoes around Quito constantly indicate a strong wind from the east. On the accompanying map, fig. 2, the isobars and surface winds for July are copied from Hann's Atlas der Meteorologie, while the long arrows indicate the directions of movement of the cirrus clouds in July. We see that there is a broad upper stream flowing from the east both above and on each side of the thermal equator. At Manila the direction is east-northeast, in India southeast, Congo east-southeast, Guiana and Costa Rica due east, Jamaica and Havana east-southeast, though in winter it is west-southwest at Havana. In about latitude twenty degrees the direction is west-southwest at Key West and west-northwest at Mauritius, while over the whole temperate zone of the Northern Hemisphere, from the United States in the west, to Assam and Shanghai in the east, westerly winds prevail. At Melbourne the direction is also west 16° north. In fig. 1 are given the mean monthly directions of the upper clouds extracted